MEDICINAL AND AROMATIC PLANT VARIETIES RESISTANT TO DROUGHT

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Abstract. The climate change in recent decades imposes the cultivation and use of plant varieties that are adapted to drought conditions, high critical temperatures and ensure high productivity. It has been shown that the consequences of drought can be substantially diminished by cultivating drought-resistant varieties of the aromatic and medicinal species such as *Salvia sclarea, Lavandula angustifolia* and *Salvia officinalis*. The early-, mid- and late-ripening *Salvia sclarea* varieties Ambra Plus, Balsam, Parfum Perfect, Ambriela, Dacia 99; Victor; Nataly Clary are very resistant to drought; they accumulate in dry years high content (0.916-1.202%) of essential oils, provide a production of 15.1-22.4 t/ha of inflorescences in two years of plantation exploitation and guarantee yields of 41.1-77.4 kg/ha of essential oil depending on the variety. The efficiency of *Salvia sclarea* varieties ranges between 2.8 and 3.6 kg per ton. The essential oil content of *Lavandula angustifolia* varieties is higher (5.103-6.164%) in dry years than in those with common atmospheric depositions (4,318-5,915%). The productivity of the lavender varieties Moldoveanca 4, Vis Magic 10, Alba 7, Aroma Unica etc. is higher and makes 7-12 t/ha of inflorescences with high content of essential oil (4.575-6.164%) and 121.1-182.6 kg/ha of essential oil. The efficiency varies from 16.8 to 21.5 kg of essential oil per ton of inflorescences. Variety Miracol of *Salvia officinalis* drought-resistant ensures a production of 850-989 kg / ha of dried leaves in the dry years and 960-1070 kg / ha of ordinary habitat. The production of essential oil of the variety in the dry years is higher (18.7-18.9 kg/ha) than in the years with common atmospheric depositions (17.2-17.6 kg/ha).

Keywords: Medicinal plant, *Salvia sclarea*, *Lavandula angustifolia, Salvia officinalis*, variety, drought resistance, productivity.

Rezumat. Soiuri de plante medicinale şi aromatice rezistente la secetă. Schimbările climatice din ultimele decenii impun cultivarea și utilizarea soiurilor de plante care sunt adaptate condițiilor de secetă, temperaturilor critice ridicate și care asigură o productivitate ridicată. S-a demonstrat că consecințele secetei pot fi diminuate în mod substanțial prin cultivarea soiurilor rezistente la secetă din speciile aromatice și medicinale, cum ar fi *Salvia sclarea, Lavandula angustifolia, Salvia officinalis*. Soiurile de *Salvia sclarea* timpurii, medii şi tardive Ambra Plus, Balsam, Parfum Perfect, Ambriela, Dacia 99; Victor; Nataly Clary sunt foarte rezistente la secetă. Acestea acumulează în anii secetoşi un conţinut înalt (0.916-1.202%) de ulei esențial, asigură o producție de 15,1-22,4 t/ha de inflorescențe în doi ani de exploatare a plantațiilor și garantează o producţie de ulei esențial de 41.1-77.4 kg / ha în funcție de soi. Eficiența, randamentul soiurilor de *Salvia sclarea* variază între 2,8 și 3,6 kg per tona de materie primă. Conținutul de ulei esențial al soiurilor de *Lavandula angustifolia* este mai mare (5.103-6.164%) în anii secetoși decât în cazul celor cu depuneri atmosferice obișnuite (4,318-5,915%). Productivitatea soiurilor de lavandă este înaltă: 7-12 t/ha de inflorescențe cu conținut ridicat de ulei esențial (4.575-6.164%) și 121.1-182.6 kg/ha de ulei esențial. Eficiența variază de la 16.8 până la 21.5 kg de ulei esențial pe tonă de inflorescențe în funcție de soi. Soiul miracol de *Salvia officinalis* rezistent la secetă asigură o producție de 850-989 kg/ha de frunze uscate în anii uscați și 960-1070 kg/ha în anii obișnuiți. Producția de ulei esențial al soiului în anii uscați este mai mare (18,7-18,9 kg / ha) decât în anii cu depuneri atmosferice obișnuite (17,2-17,6 kg / ha).

Cuvinte cheie: Plante medicinale, *Salvia sclarea*, *Lavandula angustifolia, Salvia officinalis,* soiuri, rezistenţă la secetă, productivitate.

INTRODUCTION

The importance of medicinal and aromatic plants is indisputable in view of the revival of phyto-pharmacy and herbal treatments. Thus, the share of drug products from medicinal and aromatic plants and their derivatives has been constantly growing. More than 50% of the prescribed drugs are chemical derivatives identified for the first time in medicinal plants. Around 50 -70 thousand plant species are used in medicines throughout the world (ROSE, 1981). The use of these plants for medicinal, perfumery, cosmetics reasons is due to the essential oil and its components separated from inflorescences. Given the fact that about 3500 tons of essential oils, 10,000 tons of food additives, 10,000 tons of perfumery additives are produced in the international cultivation of varieties of the medicinal and aromatic plants are strictly necessary, thus guaranteeing the steadfast production of high quality pharmaceutical, perfumes, and food raw materials, with a much more enhanced content of active principles in comparison with the types collected in wild flora. On the other hand, they provide an important source of income in rural areas. All of these have influenced constantly the studies on the chemical composition, qualities and benefits of using flowers, leaves, essential oils and other derivatives of medicinal an aromatic plant, including, *Lavandula angustifolia* Mill., *Salvia sclarea* L., *Salvia officinalis* L. etc. well as the diversity of essential oil use depending on its qualitative and quantitative composition.

A particular research area includes the studies carried out to develop new hybrids and varieties that are resistant to abiotic factors that would ensure an enhanced production of inflorescences with a higher content of essential oil and a quality that corresponds to the envisaged purpose. Such studies have obviously intensified during the last decades as a consequence of the climatic changes, slow but steady processes of global warming, transformation of some zones into a desert including in south-eastern Europe where farm crops are affected by drought and scorching heat more and more frequently. Simultaneously, our researches show that the cultivars of medicinal and aromatic plants

(*Lavandula angustifolia*, *Salvia sclarea*, *Salvia officinalis*, *Anethum graveolens*, *Origanum vulgare* etc.) provide an enhanced production of raw material and high-quality essential oil in dry years. Some of these cultivars such as lavender accumulate a content of essential oil that is even higher in dry years than in the years with common atmospheric depositions.

MATERIAL AND METHODS

The biological material comprises *Salvia sclarea* L.*, Salvia officinalis* L., *and Lavandula angustifolia* Mill varieties of different hybrid origins. Thus, *Salvia sclarea* cultivars are hybrids with fixed, constant heterosis (GONCEARIUC et al., 2016) of different complexity: simple (Dacia-50, Dacia-99, V. Junior, Victor), triple (Nataly-Clary, Parfum Perfect), backcross (Ambra Plus) and stepwise (Balsam, Ambriela) hybrids. The *Lavandula angustifolia* varieties Moldoveanca 4, Vis magic 10, Alba 7 and Aroma Unica as well as new varieties in the testing process (Fr.8-5-15V; VM-18V; Fr.5S8-24) are first-generation hybrids with a high heterosis effect on a number of quantitative traits including essential oil content (GONCEARIUC, 2018; GONCEARIUC et al., 2018). The validation of the quantitative traits and productivity of all varieties was carried under legal methods. The essential oil content was assessed in fresh inflorescences at the stage of industrial maturity through hydrodistillation in the Ginsberg apparatus and recalculated for dry matter.

The weather conditions in the years of conducting the studies were as follows:

The agricultural years 2012, 2015 and 2018 were dry according to the reports of the State Hydro meteorological Service of the Republic of Moldova. The summer of 2012 was recorded as the hottest, the average temperature of the air exceeding the norm by 3-4ºC per season. Rainfall in the spring-summer period was 238.9 mm, compared to the multiannual average of 308 mm; the amount of annual precipitation being 378.3mm or 69.1 mm lower than the multiannual average (526 mm). In 2015, the annual precipitation amounted to 480.5 mm, by 45.5 mm lower than the multiannual average. During the spring-summer period, 205.2 mm of rainfall were recorded, the multiannual average being 308.0 mm. The largest humidity deficit was attested in June-August: the precipitation amount was only 85.1 mm, or 100.9 mm lower than the multiannual average of 186 mm. 2018 is a special year characterized by an abnormally hot spring, when the average monthly air temperature in April exceeded the norm by 4.5-5.5ºC, a fact reported for the first time in the entire observation period. The temperature of the soil during May - August ranged between 58.7 and 64º C. Precipitations were only 3.7 mm in April, and reached 17.5 mm in May, by 35.3 and 34.5 mm lower, respectively, than the multiannual norm. August was also very dry with 0.6 mm of atmospheric deposits. Drought periods alternated with heavy rainfall, which provided a total annual rainfall that did not differ much from the multiannual average, or both the periods of acute drought and those with heavy rainfall were accompanied by very high temperatures.

The agricultural years 2013, 2014, 2016, 2017 are characterized by an amount of precipitations in the spring - summer period ranging from 316 mm in 2013 to 380.2 mm in 2017; the amount of annual rainfall was 608 mm in 2013, 86 mm higher than the multiannual average; 524.6 mm in 2014, 1.4 mm lower than the multiannual average; 567.6 mm in 2016, by 41.6 mm exceeding the multiannual average; 641.4 mm in 2017, or 115.4 higher than the multiannual average.

RESULTS AND DISCUSSIONS

Previous research has shown that intraspecific hybridization is an efficient method to develop valuable genotypes through pronounced variability of the indices of bio morphological character values including the content and components of essential oil in *L.angustifolia, S. sclarea* and *S. officinalis* (GONCEARIUC, 2014, GONCEARIUC et al., 2016; GONCEARIUC, 2018). Importantly, our hybrid varieties are strongly resistant to drought (GONCEARIUC et al., 2016; 2018). In contrast to other *S. sclarea* cultivars, the ones we have developed begin flowering in the first year of vegetation providing both production of 3-5 t/ha of inflorescences and 12-20 kg/ha of essential oil. So, the cultivar Ambra Plus is distinguished by abundant flowering and the yields of inflorescences make up to 11 t/ha and 40.9 kg/ha of essential oils in the first year (Table 1.). The production of raw material of all *Salvia sclarea* varieties in drought condition of the 2015 year constituted between 3 and 8 t/ha, in dependence on the variety. The content of essential oil was higher in the cultivar Balsam (1.286%). The production of essential oil varied between 5.7 kg/ha in the cultivar Nataly Clary and 11.6 and 12.5 kg/ha in the cultivars Ambra Plus and Balsam, respectively. Also, in the dry year 2015, the second year of vegetation, all the varieties produced high quantities of raw material (12.1- 18.7 t/ha) and essential oil (32.5-58.8 kg/ha) (GONCEARIUC et al., 2018).

The inflorescence yields, the content and production of essential oil are supported by a number of quantitative traits. The indices of their values were remarkable in the dry 2015 year: the plants formed a great number of floral stems per m^2 and the plant's height of 117.7-125.1 cm, long inflorescences (56.7-64.3 cm) with a large number of ramifications, high content of essential oil, which shows excellent development under drought conditions.

In the two years of exploitation (2014-2015), the yields of raw material were 15.1 t/ha – 22.4 t/ha, and essential oil production varies between 41.1 n 77.4 kg/ ha depending on the variety (Fig. 1).

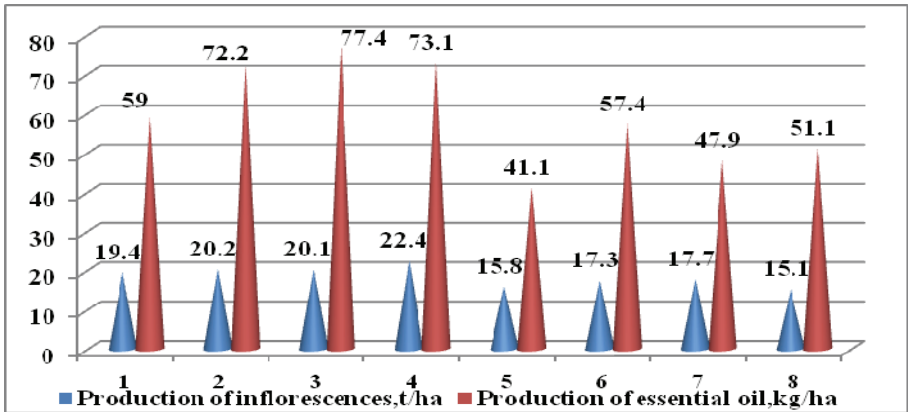

Figure 1. The producing capacity of the *Salvia sclarea* varieties in two years of plantation exploitation, 2014-2015: 1. Dacia-50,st.; 2. Ambra Plus; 3. Balsam; 4. Parfum perfect; 5. Dacia 99; 6. V. Junior; 7. Victor; 8. Nataly Clary.

The 2018 year in the Republic of Moldova was also dry. Under these conditions, the varieties of *S.sclarea* in the second year of vegetation formed high yields (10.7-13.9 t/ha) of inflorescences with high content of essential oil (0.859-1.202%) (Table 1). Essential oil production in the second year of vegetation consisted of 27.6 to the standard variety up to 43.1 kg/ha at variety Ambriela.

In two years of operation of the plantation, the yield of the raw material ranged from 14.4 t/ha for the standard variety to 23.2 t/ha for the Ambra Plus variety and essential oil production ranged from 51.8 kg/ha attested for Dacia 99 to 73.6 kg/ha for the Ambra Plus variety. The efficiency of all varieties is very high: 3.3-3.6 kg/t in the first year of vegetation and 2.7-3.6 kg/t in the second year that was dry (Table 1).

The high productivity of these varieties is sustained, influenced by the values of the quantitative characters of plants. In drought conditions (2018), the tested varieties formed a large number of floral stems (44.4-69.1/m^2), long inflorescences (52.7-70.0 cm) with large number of branches, which shows an excellent plant development. All of this has resulted in a high content (0.858-1.202%) of essential oil (Table 2.) and high productivity (Table 1).

Table 1. The productivity of *Salvia sclarea* L. varieties, first & second years of vegetation, 2017-2018*.

Variety, hybrids	Row material yield, t/ha		Essential oil content, %		Essential oil production kg/ha		Efficiency, kg /t	
	2017 Ist year	2018* IInd year	2017 Ist year	2018* IInd year	2017 Ist year	2018* IIndyear	2017 Ist year	2018* IIndyear
early varieties								
Dacia-50, st.	3.7	10.7	1.120	0.858	12.5	27.6	3.3	2.7
Ambra Plus	11.7	11.8	1.163	0.916	40.9	32.6	3.5	2.9
Balsam	8.9	12.8	1.131	1.015	30.1	39.4	3.4	3.1
Ambriela	8.3	11.9	1.215	1.202	30.3	43.1	3.6	3.6
Parfum Perfect	7.8	12.2	1.132	1.086	26.5	39.9	3.4	3.3
middle variety								
Dacia 99	3.8	12.2	1.097	1.070	12.6	39.2	3.3	3.2
late varieties								
Nataly Clary	3.8	13.9	1.187	1.036	13.7	43.3	3.6	3.1

* dry year DL, 0,5 1.1 1.2
P, % 2.0 2.1

Table 2. The values of some productivity indices in *Salvia sclarea* varieties in competitive crops, 2018.

Variety	Floral stems/ m^2	Plant height, -cm-	Inflorescence length, -cm-	Inflorescence branches, number		Essential oil content, % (dry matter)
				Grade I	Grade II	
		X ± Sx	X ±Sx	X ± Sx	X ± Sx	
early varieties						
Dacia-50 st.	46.5	138.6±7.4	66.9±7,9	16.0±2.1	25.4±6.2	0.858
Ambra Plus	54.7	137.1±8.0	67.9±6,7	15.8±1.7	25.9±8.0	0,916
Balsam	46.4	138.2±7.2	66.4±6.4	15.4±1.8	21.7±4.8	1,015
Parfum Perfect	60.0	143.2±8.8	69.2±6.7	15.0±1.9	23.0±6.4	1.086
Ambriela	54.6	141.0±7.8	70.0±7.9	16.1±2.7	22.6±5.7	1.202
middle variety						
Dacia-99	55.7	135.7±9.9	63.4±8.3	15.5±2.3	24.3±8.2	1.070
late varieties						
Victor	69.1	138.8±9.5	64.4±7.9	15.6±2.1	25.0±6.8	0.815
Nataly Clary	58.6	120.9±6.0	52.7±5.3	14.4±1.9	20.1±4.4	1.036

The productivity of other varieties of *Salvia sclarea*, such as the Ukrainian variety Krymsci ranii, and the Russian variety Voznesenskii 24, cultivated in the Republic of Moldova until 1992-1994 did not bloom in the first year

of vegetation. In the second year of vegetation, the productivity of these varieties was10-13 t / ha of the raw material and 8-12 kg / ha of essential oil with an efficiency about 2 kg / t of essential oil.

The hybrid varieties of lavender accumulate enhanced content of essential oil in drought conditions than in the years that are not affected by drought (GONCEARIUC, 2018; GONCEARIUC et al., 2018) (Table 3). In 2015, this important trait ranged from 4.575-6.164% in the cultivar Vis Magic 10 to 6.164% in the cultivar FR.5S8-24.

It is well known that severe drought has a negative effect on perennial species both in the year of major humidity deficiency and in the years that follow. The consequences of the 2015 drought were different in the case of the lavender cultivars. The F_1 hybrids recorded a higher content of essential oil in the 2015 than in the 2014, 2016, 2017 and 2018 exceeding the maternal form of origin (GONCEARIUC et al., 2018). Similar results were recorded in the years of severe drought 2007 and 2012.

Table 3. The content of essential oil in the varieties (hybrids) of *Lavandula angustifolia*.

Varieties (hybrids F_1)	**Essential oil content, % (dry matter)**				
	2014	**2015, dry year**	**2016**	**2017**	**2018, dry year**
early varieties					
Moldoveanca 4 st.	4,893	5.404	4,318	4,981	4.611
Fr.8-5-15V	4,545	5.803	4,691	5,454	5.624
middle variety					
Vis Magic 10 st.	4,423	4.575	4,597	4,518	4.741
VM-18V	4,710	5.103	4,924	4,829	4.872
late varieties					
Alba 7st.	5,298	5.762	5,915	5,256	5.624
Fr.5S8-24	5,087	6.164	5,786	5,915	5.656
Aroma Unica	4.901	5.496	4.899	4.961	5.476

The average producing capacity of the lavender varieties in drought conditions with different vegetation periods ranges between 6.9 t/ha of raw material (inflorescences) in the cultivar VM-18V and 8.9-10.8 t/ha in the cultivars Aroma Unica and Moldoveanca 10 (Table 4). The production of essential oil makes 121.1-182.6 kg/ha depending on the cultivar.

In the years with common atmospheric deposition, the productivity of lavender varieties is 7.4-12.4 t/ha and 132.8-250 kg/ha essential oil depended on the variety (GONCEARIUC, 2014; 2018; GONCEARIUC et al., 2018). These cultivars are also distinguished by high efficiency – one ton of raw material ensures obtaining from 16.8 to 21.5 kg/t of essential oil with content of linalyl acetate making 28 to 39%. This index is 44% in the new cultivars Aroma Unica etc. It should be mentioned that all developed cultivars and hybrids have a low concentration (0.21-0.27%) of camphor in the essential oil (GONCEARIUC, 2014; GONCEARIUC et al., 2018), this component being important as it diminishes the quality and perfumery value of essential oil in high concentrations (more than 2%). In the essential oil Bulgarian lavender varieties, the concentration of camphor is much higher 6.6-9.2% (ZHELJAZKOV et al., 2013). The productivity of Bulgarian lavender varieties is as follows: 6.3-6.9 t/ha fresh raw materials; 1.9-2.0% essential oil in fresh inflorescence; 49.2-180 l / ha production of essential oil (YANCHEV, 2017).

Table 4. Productivity of *Lavandula angustifolia* varieties in drought conditions, 2018.

Variety	**Row material yield, t/ha**	**Essential oil content, %**	**Essential oil production, kg/ha**	**Efficiency, kg /t**
Early varieties				
Moldoveanca 4, st.	10.8	4.611	181.7	16.8
Fr.8-5-15V	8.5	5.656	161.9	19.0
Middle varieties				
Vis Magic 10, st.	8.3	4.741	143.3	17.3
VM-18V	6.9	4.872	121.1	17.6
Cr.13S-6-7	7.9	4.012	136.4	17.3
Late varieties				
Alba 7, st.	7.6	5.624	134.7	17.7
FR.8-5-15V	8.5	5.624	182.6	21.5
Aroma Unica	8.9	5.476	166.8	19.9

The early ripening variety of *S. officinalis* named Miracol as well as varieties of *L .angustifolia* and *S. sclarea* is resistant to drought, frost and wintering. The variety can be used to produce pharmaceutical raw material of *Folium Salviae*, *Herba Salviae* and essential oil – *Oleum Salviae* (GONCEARIUC, 2014).

The producing capacity of the variety Miracol is 850-989 kg/ha of dry leaves (13% of humidity) in drought conditions (2012, 2015, 2018) and 960- 1070 in the years with common atmospheric deposition (Table 5).

A similar content of essential oil as in the Miracol variety was described for the Crimea variety Predgornyi (1.6%). Most of the scientific publications regarding *Salvia officinalis* are about the quantitative and qualitative components of the essential oil, but not the production of raw material, essential oil. The essential oil chemical composition of this species is very variable (BERNOTIENĖ et al., 2006; GONCEARIUC et al., 2012).

Table 5. Yield of *Salvia officinalis* L. variety Miracol.

Years	Yield of raw material, kg/ha		Essential oil content, August 15-20, % (dry matter)	Production of essential oil kg/ha
	Humidity 60%	Humidity 13%		
2012*	2990	850	1.890	18.7
2013	2930	960	1.540	17.4
2014	3055	1029	1.498	17.6
2015*	2989	920	1.835	18.9
2016	3010	980	1.640	17.5
2017	3090	1070	1.596	17.2
2018*	3025	989	1.748	18.9

22 components were identified in the essential oil separated from shoots wits leaves of the variety Miracol. The concentrations of major compounds in the essential oil are: α-thujone, 33.791%; β- thujone, 5.877%; camphor, 24.59%, eucalyptol, 8.416%. In essential oil separated from leaves, the major compounds are: α-thujone, 21.239%; β-thujone, 16.201%; camphor, 19.133%; eucalyptol, 10.372% (GONCEARIUC et al., 2012). In the essential oil separated from the varieties Extracta, Regula, and IPPO the major components are also α- and β-thujone but also 1.8 cineole (GIUSEPPE DE MASTRO, 2006). The chemical composition of *Salvia officinalis* essential oil from Bulgaria are: α-thujone (26.68%), (E)-β-caryophyllene (7.47%), 1,8- cineole (7.19%), α-humulene (6.11%), β-pinene (5.44%), β-thujone (5.35%), camphor (4.84%), allo aromadendrene (4.55%), borneol (3.69%), and α-pinene (3.58%) (DAMYANOVA et al., 2016). In *Salvia officinalis* essential oil from North America was described in different varieties four principal constituents in a concentration of about 10%: camphor, α-thujone, β-thujone, 1.8 cineole which form five chemotypes (TUKER, MACIARELLO, 2011).

The production of essential oil obtained from steam distillation of fresh raw material Miracol variety is about 18.7-18.9 kg/ha in dry years and 17.2-17.6 kg/ha in common years.

Thus, climate changes in recent decades imposed the cultivation and use of medicinal and aromatic plants varieties that support drought, high critical temperatures and ensure high productivity.

CONCLUSIONS

1. The consequences of drought can be substantially diminished by cultivating drought-resistant varieties of aromatic and medicinal species such as *Salvia sclarea*, *Lavandula angustifolia* and *Salvia officinalis*. The results of our research demonstrate: dry years favour the varieties created by us through the synthesis of essential oil, guaranteeing high productivity and quality.
2. The *Salvia sclarea* cultivars Ambra Plus, Balsam, Parfum Perfect, Ambriela, Dacia 99; Victor; Nataly Clary are resistant to drought and, in the dry years, accumulate a high content (0.858-1.202 %) of essential oils, provide a production of 15.1-22.4 t/ha of inflorescences and guarantee yields of 41.1-77.4 kg/ha of essential oil depending on the variety. The efficiency of *Salvia sclarea* varieties ranges between 2.7 and 3.6 kg/t of essential oil per ton of raw material.
3. The essential oil content of *Lavandula angustifolia* cultivars in drought conditions is higher (4.575-6.164%) than in those with common atmospheric depositions (4,318-5,915).
4. The productivity of the lavender cultivars Moldoveanca 4, Vis Magic 10, Alba 7, Aroma Unica, etc. in drought conditions ensures yields of 6.9-10.8 t/ha of inflorescences and 121.1-182.6 kg/ha of essential oil depending on the variety. The efficiency varies from 16.8 to 21.5 kg of essential oil per ton of inflorescences.
5. Variety Miracol of *Salvia officinalis* drought-resistant ensures a production of 850-989 kg/ha of dried leaves in the drought conditions and 960-1070 kg / ha in conditions of normal habitat. The production of essential oil of the variety in the dry years is higher (18.7-18.9 kg / ha) than in the years with normal atmospheric depositions (17.2-17.6 kg/ha).

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